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Comparing the spirilla from the cases of relapsing fever with those from the ulcer, no difference could be made out.

Films of pus from the gums showed *Spirilla buccæ* and bacillus fusiformis of Vincent; these spirilla were also indistinguishable from the two spirilla mentioned above. The pus from the gums of the case of relapsing fever showed during the whole of the periods of pyrexia and apyrexia the two organisms of Vincent.

Had the present case then suffered from relapsing fever? It seems most probable that he had; question then is what is the relation between these spirilla. It is to be regretted that neither spirillum buccæ or bacillus fusiformis have yet been cultivated; both of them are actively motile and, as Dr. A. E. Wright has recently pointed out in the *Lancet* that bacillus fusiformis is very like a trypanosome. Professor Schaudinn has recently found that the spirochæte obermeiri of relapsing fever is but a phase in the life history of a trypanosome, that it has a large nucleus and micro-nucleus and, further, that it also alters its shape contracting so as to present a form of a minute oval or pear-shaped body provided with a large and smaller nucleus.

I regret I was unable to further study this interesting case as the man left the hospital during the night and could not be found again.

There is yet good deal of research to be done on human spirillosis. I believe spirilla have been found in an abscess, but I am unable to say by whom. I trust these few notes may stimulate further research in this direction.

PLAGUE, RATS, AND FLEAS.*

BY W. G. LISTON,
CAPTAIN, I.M.S.

(Read before the Bombay Natural History Society, on 24th November, 1904.)

You may perhaps think that the choice of such a title for a paper to be read before a Natural History Society is somewhat out of place, and would have been more suitable for a medical gathering. Perhaps you are right; but I feel sure that the subject has a proper place under the circumstances. We are daily becoming more aware of the important part played in the spread of disease by the numerous animals and insects which surround us, and, as you will learn in the course of my remarks, plague is a disease which is pre-eminently dependent on such surroundings. A knowledge of Natural History is becoming a more important, I may say an all-important branch of the medical profession. Quite apart, however from such facts, plague is in the midst of us, carrying on its deadly ravages, and adding daily to its already uncountable death-roll hundreds, who, through ignorance of its mode of spread, fall victims to the scourge. Any ray of light shed into the darkness which surrounds the ætiology of this disease should not be confined to the medical world, but be cast upon the people, that they may perhaps be enabled thereby to grope their ways through the darkness to a place of safety.

You will appreciate the relation between Natural History and Plague when I define the latter as a rat

disease. Not unfrequently under favouring circumstances it is communicable to man. The disease among men, therefore, might almost be said to be accidental, and certainly avoidable if there were a distance between rats and men. The communication of the disease to man is conditional on the propinquity or distance of rats and men from one another; and is dependent partly on the habits of the former, and partly on the modes of living of the latter.

The ideas embodied in the above definition are not new. That plague is essentially a rat disease was known to the ancients. We find the disease attributed to these animals by the priests and diviners of the Philistines, who instructed the people in these words—"Make images of your emerods and images of your mice that mar the land." They were to do so as a trespass offering to the God of Israel.¹ In the Bhagavathi Purana the people are advised "at the moment rats fall from the roof above, jump about, and die" to leave their homes with their friends and relations, and to live in the plain.² In Kumaun, where the disease has been known for long, the experience of the inhabitants has taught them that when rats die, it is time to quit their homes for the jungle to save themselves from plague. It is stated in a report of the outbreak of 1834-35, that "the appearance of the disease in a village had been observed to be preceded by a mortality among the rats of the village."³ Coming to more recent times, Hankin, in reviewing the various circumstances that produced plague in Bombay inferred that the incidence of plague in localities and houses was in relation to their accessibility to rats rather than to filth, overcrowding, etc.⁴ Simond also came to a similar conclusion from his experience of the disease.⁵

Dr. Ashburton Thompson, from his experience of the outbreak of plague in Sydney in 1900, formed the opinion that plague rats constituted the sole source from which the infection was communicated to man.⁶ Dr. G. J. Blackmore, formerly Chief Plague Medical Officer, Port Elizabeth, very clearly and conclusively proved that the epidemic in that town was altogether spread by rats. He writes: "To sum up shortly, in places where infected rats were found plague cases followed; and in place where there were no infected rats, only four cases of plague occurred, and in these cases the source of infection could not be traced at all. In no case was there direct evidence of man to man infection, and in most cases the possibility of it was definitely excluded." I need not quote further in this connection. *It is absolutely certain that rats are the most important factor in the spread of plague.* If plague is a disease of rats, then it is likely that the disease may have its own distinct laws of origination and continuance among these animals; man becoming affected chiefly when the disease is most prevalent among rats. It is precisely this study of plague among rats that has been neglected. Before any progress in this connection can be made, it is necessary to know something about the life and habits of rats.

What do we really know about rats? Very little. Now this is one reason why I am reading this paper before you to-day. You are all naturalists, and no doubt keen observers. May I ask you to direct your attention to rats? Any notes upon the habits of these animals will be thankfully received by me.

Let me here discuss some of the important facts connected with the habits of rats, which have a bearing on the development and spread of plague, so far as they are known to me. In the first place, as you are aware, there are various genera and species of rats. I have tried to classify (more or less casually I must admit) the Indian town or village rats; but I have completely failed. There appear at first sight to be many species. I visited the British Museum when at home, and saw Mr. Oldfield Thomas on this subject; and he assured me that any rat I sent from Bombay would be likely to be either a *Mus rattus* or *Mus decumanus*. I was discussing this matter the other day with a member of this society, Mr. Aitken, and he suggested that it might

* Revised copy sent for publication.—ED., I.M.G.]

be as easy to classify pie-dogs as the rats in Bombay. I am inclined to agree with him. There is apparently one fact evident that Mr. Oldfield Thomas is quite right in distinguishing only two *very distinct* species of domestic rat—*Mus decumanus* and *Mus rattus*.

Mus decumanus, the brown rat, or Norway rat, is a large rat which in European countries has gradually displaced the smaller black rat, *Mus rattus*. This brown rat is much more a burrowing rodent than the black rat, and likes to live in drains and cellars; while the black rat prefers the roofs of houses, and even trees to live in. The black rat, then, is in a truer sense a domestic rat; and it is the common domestic rat of India. This fact is an extremely important one from the point of view of plague. The immunity of European countries in the present day can to a large extent be attributed to the ousting of the black rat by the brown rat. The changes in the habits of man in European countries within the last two or three centuries, the development of drainage systems, the separation of workshops from dwelling-houses, the isolation of granaries and stables from human habitations, has led to the extermination of the black rat or at least to its separation from man. The opportunities for the infection of man with plague from rats have thereby been lessened, and consequently in Europe the development of plague in rats runs almost independently of the development of the disease in man. No more striking instance of this can be given than the experience of Glasgow.⁶ Plague first broke among the people of this city in the autumn of 1900; thirty-six attacks with sixteen deaths was the result of this epidemic. The origin of the disease could not be traced. All the cases were more or less associated with one another, and arose chiefly from three houses in which "wakes" were held over the bodies of individuals who had died of plague in the houses. At the time of this epidemic no rats were found affected with plague. There is good reason to believe, however, that although not found, yet the epizootic actually existed; for, after an interval of a year, a second outbreak occurred, this time among individuals associated with a rag store. Rats affected with plague were found here, and continued to be found affected with the disease in various parts of the city, at irregular intervals, for a period of two years. The only epidemic plague associated with this epizootic plague was that which occurred in some five individuals who worked in the rag store, and in other five individuals who worked or lived in the cellars of the Central Hotel. Plague-infected rats were found in the basement of certain tea rooms in Gordon Street. A rat warren was discovered, which, when the burrows were broken up, gave a bag of 67 rats which had either been killed or found dead. Of these 67 rats no less than 40 had plague. Rats affected with the disease were found in other places, and continued to be found, as I have remarked, for nearly two years; but no plague occurred in men. It is evident we were here dealing with epizootic plague among rats of the species *Mus decumanus*. You note the diseased animals were found in cellars and burrows, places where rats of the species *Mus decumanus* are generally found, places where they were more or less isolated from man. Had the epizootic occurred among rats of the species *Mus rattus*, which inhabit houses, a very different tale would have been told. It is interesting to note the gradual disappearance of plague from Europe about the end of the 17th century, a time which was coincident with the invasion of the brown rat, and the displacement of the black rat by that species. The species of rats affected by the disease has an important bearing on the spread of plague in man, not from any inherent difference in susceptibility to the disease in the particular species of rat, but because of the habits of the species. Another important difference will be noticed when I came to describe the fleas infesting these species of rats.

Now while there is the striking difference in the habits of the two species of rats, we have equally striking

differences in the habits of the people inhabiting Europe and the East. I have referred to the fact that perhaps the invasion of Europe by the brown rat may have been aided by the change in the habits of the people. As pucca buildings became to be erected, as drainage systems developed, as stables were separated from dwelling-houses, as shops, warehouses, and granaries were no longer used as human habitations, as stone and wooden floors displaced mud and rush-covered ground, as beds became used in place of heaps of straw, so the black rat was driven from its haunts and the brown rat had it all his own way. Man and rats were separated from one another, and plague ceased to trouble; for, as will be shown later, man plays an important part in spreading the disease among rats.

An observant correspondent, the Revd. J. H. Lord, who is much interested in the origin and spread of plague, very briefly put it as follows:—

"What a timid and scared animal a rat is at home, living away in sewers or barns or hay stacks, as a rule only occasionally venturing among men. But here, in India, on the contrary, it is a confiding, almost domestic animal, encouraged to impudence by the very aversion of Hindus to the destruction of animal life, while on the other hand, modes of human life out here cause masses of people to live huddled together, in what are almost barns and warehouses, in closest contact with rats; and throughout the East it is more or less so, and I would even suggest that the plague has been able to catch on at various places more or less according as conditions are similar or dissimilar to what I have described, e.g., at Alexandria, the Cape, Lisbon, Glasgow, etc.; and also, when the plague in the Great Plague of London did catch on there, was it not perhaps because people were living a good deal in the insanitary way, then, as to overcrowding and contact with rats, etc., that they do in the East now?"

So much for the difference between the two species of rats, the habits of each species, and the habits of man, which bring men and rats more or less in contact with one another.

Rats, like men, are gregarious creatures; they have their communities in each town or village, communities which have little or no intercourse with one another. They have their maharwaras and bunispuras; some live upon the refuse of the people, others install themselves in the granaries of the rich; little communication, as I have said, takes place between these communities; but still less communication can there be between the rats of one town and those of another except through human agency. Our high sea-ways, railways, and cart roads, all of them channels for the conveyance of merchandise, act also as a means of communication between the rats of one town with those of another; stray individuals are carried along with merchandise; stowaways, as they might be called, are taken from one town to another. This is only a chance means of communication between rats of one place and those of another; and the chances are of course greater where the means of conveyance is larger. Ships transport rats therefore in this way much more frequently than railway trains; and railway trains more frequently than carts.

Another habit of rats must here be considered, a habit too, in which they resemble uneducated men. On the occurrence of any unusual mortality, from any cause, among a community of rats, they quit the place where the mortality has occurred; they migrate as a community. In this way infection is often communicated from one community of rats in a village or town to another in the same village or town. Here a fresh focus of infection may, in consequence, be set up. Occasionally some individuals of such a migrating community may seek refuge in a ship or railway train or cart and may carry this infection through human agency to another town. This is one important way in which plague may be spread from one place to another by human agency. Seaport towns, as will be under

stood from what has been said above, are most frequently infected in this way. I would instance Sydney, Port Elizabeth, Durban, Lisbon, Glasgow, etc.

But there is another means of communicating the disease by means of human agency from rats of one town to those of another town, which will be discussed later when the part played by fleas in the spread of the disease is considered. I mention this fact here because it becomes possible only in connection with the migrating tendency of rats. I need hardly discuss at length this migrating instinct (shall I call it? which impels rats to shun places which are associated with their death or destruction. Who has not set a trap for rats and found, that after two or three have been taken, the rats will not look near the trap again? Who has not noticed, that if a good dog or cat is introduced upon rat-infected premises, after a few of the animals have been destroyed, the others disappear? Who has not noticed, that poison placed for rats will cause the disappearance of far larger numbers of them than are actually destroyed by the poison? This habit of migration, due to fear of destruction, is a very important habit of rats in the spread of plague. I should like, however, to emphasize the fact that the extent of the migration is proportionate to the severity of the destruction. Thus, if a trap is set, say, in one room which is frequented by rats they will probably quit that room for a neighbouring room. But if a wholesale destruction is produced as by placing poison in several places in a house, the rats will quit the house completely. Just so is it with plague. If conditions are such as are unfavourable to the rapid spread of the disease, the infected rats may linger on in a particular house, not being so thoroughly scared by the moderate mortality as to quit the house; infection may thus smoulder on in a particular house till the conditions become favourable to the extensive spread of the disease. I shall now consider what these favourable conditions are. They are associated with the breeding season of rats, and are due to the increase in the number of susceptible individuals and the multiplication of fleas, the carriers of infection.

The season at which the greatest number of young rats are present has a two-fold influence on the spread of plague. In the first place, the arrival of young members among the community increases the number of individuals susceptible to the disease.

In the second place, the breeding season is, as a rule, the period of increase of the fleas which are peculiar to the rat. You must be familiar with the fact that kittens and puppies are especially covered with fleas. If you wish to get a particular flea which has a certain bird for its host, your best chance of obtaining that species of flea is to find the bird's nest. So precisely is it with the rats. Rat fleas are most numerous at the time when young rats are most numerous. I fancy I hear somebody say "Oh! rats breed all the year round; they have no seasonal breeding time." This is true and it is not true. Rats do often breed all the year round; but I am equally certain that there is a season when more young rats are found than at any other season; and this season, in Bombay, is precisely the plague season. This is a very difficult matter to prove, and I should be very much obliged if any member could devise a practical method by which it could be proved. My inference has been made from observing the number of young rats brought to the Laboratory at certain seasons, and by noting the number of pregnant females which come for *post-mortem* examination. I am sorry, however, that I have no figures to offer wherewith to support by observation.

An epizootic of plague among a rat community is very often associated with a sudden and extensive spread of the disease; in proportion as there are more susceptible individuals present in that community, so the disease spreads more rapidly and extensively. A large number of the rats die from the disease; the rats become scared and migrate. The conditions in such a

migrated rat community now are: (1) there are a number of individuals which have recovered from the disease, and are therefore immune; (2) there is a greatly reduced number of individuals susceptible to the disease, because of the large number of deaths among the susceptible; (3) there are a few individuals which still harbour the disease and which have escaped with the others; (4) there is a greatly reduced number of fleas among the community, the infected fleas having for the most part been left behind. These are conditions where the chances of infection are greatly reduced, where it is possible for one case to follow another only in slow succession, where the panic of the rats, by the reduction of the mortality, has been quelled. Time passes; the disease smoulders; gradually the rats return to their old haunts, where above all other places they find food and shelter. The favourable breeding season comes round again, the number of susceptible individuals rapidly increases, and the number of fleas *pari passu* is multiplied. Conditions are re-established for a fresh and extensive outburst of the disease. Numbers of rats die from the disease. Again the rats migrate, and plague attacks man. It is thus that I would explain the seasonal endemicity of plague.

In the above remarks I have endeavoured to show the importance attaching to the particular species of rat inhabiting any place which may be subjected to plague infection. The black rat, *Mus rattus*, the common domestic rat of India, of which there are probably very many varieties, has habits such as bring it into intimate contact with man. I have tried to show that the prevalence of this rat is in great part due to the habits of men in the places where it is found, that it is possible by abolishing certain habits and customs to give the ascendancy to quite a different species of rat, which is not so domestic as the Indian rat. In short, plague is likely to spread among men in proportion as *Mus rattus* is more common, and *Mus decumanus* less prevalent; in proportion, too, as men's habits are less or more civilised. I have drawn attention to the gregarious habits of rats, which would speedily end an epizootic of plague among them, were it not for their habit of migration, which causes infection of fresh communities in the same town or village by direct intercourse; and in distant towns, through human agency, chiefly by ships or rail conveying merchandise. I have suggested that infection of rats in neighbouring towns and villages is affected by means of fleas carried by men. Finally, the breeding season of rats plays an important part in the spread of plague in man. Plague, which is essentially a rat disease, attacks men only when it is excessively prevalent among rats. The disease lingers on in these animals during the off plague season, and bursts out afresh among the rats when the number of susceptible rats is increased by births; and when the fleas, the carriers and transmitters of the infection, are more plentiful.

If plague, then, is essentially a disease of rats, are there any other diseases which are peculiar to animals, and which are occasionally communicated to man? Does a study of these diseases furnish us with any evidence which may explain by analogy how plague is, or is not, or cannot be communicated to man? How is plague communicated from rats to men?

The following are epizootic diseases which are occasionally communicated to man, and I would class plague along with them; namely, Anthrax, Glanders and Hydrophobia.

[Popular description of these three diseases omitted. —ED., I. M. G.]

Now, the plague germ does not bear spores; hence it cannot remain alive for a long period exposed to air and light and other adverse agencies, in the way the anthrax bacillus does. Nor yet has the plague germ any resistant cell-wall. Plague is certainly not conveyed to men by direct inoculation as hydrophobia is. How then can we explain the infection of men from the rat?

A little further thought on the methods of reproducing plants adopted by the *mali* will enable us perhaps to solve the problem. Has he any other method of making cuttings? Of course; there is the method of making a gooty. He selects a certain part of the plant, and ties around it some moss and earth which he keeps constantly moist. Many plants which could only be propagated by means of cuttings with difficulty, can thus easily be reproduced. Have we anything analogous to the gooty in the case of plague? I believe the flea is the gooty. The plague germs which abundantly circulate in the blood in the final stage of the disease are taken up along with the blood by the flea. I show you a specimen under the microscope which is a section through the stomach of a flea. This flea was fed on a plague-sick rat, and allowed to digest its meal for 48 hours. The result is, that almost all the blood has been digested and absorbed, and the plague germs remain unaffected, in fact, they appear to have multiplied, because they are far more numerous, than they could have been when ingested with the blood, and their appearance would indicate multiplication to one who is acquainted with bacilli which have been stained under such circumstances.

In the flea's stomach we find the plague germ in surroundings which will daily supply it with the very pabulum it desires, animal blood. The germ is not destroyed by the digestive juices of the flea. It is protected from light and dessication and the presence of contaminating bacteria (weeds in other words), conditions which would have put an end to its existence if it had remained exposed on earth. We have all the conditions which are fulfilled by the gooty in the case of the plant. The gardener after a certain time cuts off the new plant below the gooty, and transfers it to its natural soil. So, too, the germ within the flea has now to be transferred to more suitable soil, the animal body: and this is accomplished by the bite of the flea itself. The flea, being animate, fulfils the double function of gooty and *mali*.

And now, to understand the last part of my subject, it is necessary to say a few words about fleas. It would be possible to write pages on the subject. My difficulty is to tell you enough in a short space, to fully explain the relation between fleas and the plague. I hope therefore you will bear with me if I detain you a few moments longer. There are four species of fleas met with in this country commonly associated with men and rats. Specimens of these are displayed under the microscopes. I can only now mention them by name, and detail a few of the habits of these species.

The most common flea and the one most universally distributed is the cat flea, *Pulex felis*, sometimes also called *Pulex serraticeps*. This flea is, for the most part, found on cats and dogs; but it is frequently taken on man too. I have also found it on rats, monkeys, sheep, deer, goats, guinea-pigs, the hedge-hog and the horse. It is a rather small flea, but variable in size; and is of a dark colour. It is frequently found in light airy places, and it is not so nocturnal in its habits as the other fleas. Then, there is the human flea, *Pulex irritans*. It is a large fairly light-coloured flea, found almost exclusively in human habitations, and in only those of them which are dark and more or less dirty. I come now to rat fleas. The common flea found on *Mus rattus* is *Pulex cheopis*. It is therefore the common rat flea of India. It is a small light-coloured flea, which is particularly sensitive to light, loving the dark; and is therefore more or less nocturnal in habit. It is seldom found apart from the rat in this country, and lives chiefly in the haunts of the black rat, among grain bags and in the roofs of houses, etc. At first sight it is very like the human flea. The flea commonly found on *mus decumanus* is called *Ceratophyllus fasciatus*. In so far as *Mus decumanus* is rare in this country, this flea is also seldom found in India; but it is the common flea of Europe found on the rat.

These fleas can be distinguished from one another in both sexes by noting if there is a comb of bristles behind the head. *Pulex felis* and *Ceratophyllus fasciatus* have both got combs in this situation. *Pulex felis* has in addition a set of teeth-like bristles surrounding its mouth; *Ceratophyllus fasciatus* has not got these bristles. *Pulex irritans* and *Pulex cheopis* have no comb of bristles behind their head. They are readily distinguished by the length of the anti-pygideal bristles, which are short in the human flea and long in the rat flea. The claws of the human flea, too, are very large and scythe-like; while the rat flea has more elegant scycle-shaped prehensile organs. The males of all four species are at once distinguished by the characteristic shape of the claspers.

Now you will notice that most of these fleas have a particular host. The cat flea, however, is more or less an exception to this rule, for it is often found on other hosts than cat or dog. If this is the case how is it possible to explain the infection of man from the rat, when, under ordinary circumstances, the human flea is only found on man, and the rat flea on the rat? This fact, more than any other, I think, has prevented men from accepting the flea theory of the spread of plague, for not a few instances have now been reported in which plague has been directly communicated from the diseased rat to the healthy rat by means of fleas. But, it is objected, how can men become infected if the rat flea is never found on man? I have had the good fortune to discover an explanation of how the rat flea can communicate the disease to man, although normally the rat flea, *Pulex cheopis*, is scarcely ever found on man.

In March 1903 some guinea-pigs, which had died in the Victoria Gardens, were sent to me for examination. I found that they had died of plague. I immediately visited the gardens to see if I could find any fleas on the guinea-pigs; to my surprise they were covered with fleas. An examination of these fleas showed that they were rat fleas, *Pulex cheopis*. The following history of the disease was given to me by the Superintendent. A few days before the guinea-pigs became ill, dead rats had been found near their cage. The guinea-pigs had then sickened, and two keepers who had charge of them took plague and were sent to hospital. One or two of the guinea-pigs had died before the dead animals were sent to me for examination. When I saw the guinea-pigs in the gardens many were sick, but some appeared healthy. It was interesting to note that the sickly were those most infected with fleas. From one sick guinea-pig no less than eighteen fleas were removed. This is an important fact to note, in that, thereby the number of infected fleas will be greatly increased. An examination of a large number of guinea-pigs kept in our Laboratory stock showed that these animals seldom harbour fleas; the only flea found on them under normal conditions is a very occasional *Pulex felis*. This unusual infection of the guinea-pig by *Pulex cheopis* remained for some time a mystery; but an explanation was gradually forthcoming. Here, no doubt, infected rat fleas had communicated the disease to the guinea-pigs; but why were rat fleas found on guinea-pigs? The problem was solved in the following way. A friend who lived in two semi-detached bungalows kept a cat. One of the bungalows was used as a nursery for the children; and the nursery was the favourite haunt of the cat. When the hot weather came on the children were sent to the hills, the nursery was shut up and the cat had to find other quarters. About a month later my friend had to re-open and enter the nursery to get some things for the children. No sooner had he entered than he was bitten by a flea, and then by another and another, and to his surprise he found many fleas on his legs. He caught these fleas and brought them to me, and when I examined them I found them to be cat fleas. Now, as long as the cat lived in the nursery, fleas never troubled the inmates, but when the cat had been excluded, the cat fleas swarmed onto man. Starvation apparently had driven them to man.

Another opportunity presented itself in the case of a stable. This stable had been shut up for some weeks, but had formerly been inhabited by a dog as well as a horse. When the door of the stable was opened, fleas literally swarmed out into the man who opened it, almost as a hive of bees might do when disturbed. One had only to approach the stable door, and immediately one's trousers were covered with fleas. These fleas were *Pulex felis*, which we saw was the common dog flea. Here again driven by hunger, in the absence of the dog, man was attacked. Herein lies, too, the explanation of the swarms of fleas one reads and hears of in dâk bungalows in India. Somebody has been there before with dogs. The dogs left with their master, but left their fleas behind. The bungalow was shut up for a time, another Sahib entered, this time without a dog. He is immediately attacked by the fleas.

Finally, the proof was completed by the following experience for which I am indebted to the Revd. J. H. Lord. On April 20th last year he sent me some fleas which had been caught on man in a house which was infected with plague under the following circumstances. About the 6th or 7th of April rats began to die in large numbers in the chawl in which this house was situated. Suddenly the deaths amongst rats ceased, and on April 11th the people became troubled with fleas. The fleas were so numerous that they had to quit their rooms and sleep out in the verandah. While living in the verandah on April 17th one of the inhabitants of the particular room in which the fleas were taken became infected with plague. Another case occurred on the same day in a room adjoining. This room was separated from the aforementioned room only by partition 6½ ft. high. On the same day the information about this chawl came to Mr. Lord. He succeeded in getting the people who inhabited the room where the above case occurred to collect some of the fleas which they said troubled them, and he sent the collection to me on April 20th. An examination of this collection was most instructive. Now I must tell you that on previous occasions, of 246 fleas which were caught on man under normal conditions I had only found one rat flea (*Pulex cheopis*). But of the collection of 30 fleas caught on man under the circumstances above recorded no less than 14 of these were rat fleas. Nothing could be more striking.

Now what is the explanation of such unusual invasion of the guinea-pig and man by rat fleas? You note, that in both cases, a few days before, rats had been noticed dead in considerable numbers; then no more rats were found dead, and plague broke out in the guinea-pigs and men. Taking this in conjunction with the facts above recorded regarding the starved fleas, I think the explanation is that, either the rats had been almost completely exterminated by the plague, or what is more probable on the occurrence of a large number of deaths, they had migrated. In consequence the fleas which they left behind them in their nests and haunts had to seek food somewhere else, and under these circumstances had attacked the guinea-pigs and men. Herein I think we have the explanation of the common phenomenon (1) plague among rats with many deaths; (2) a lull; (3) then plague among men. Since these cases occurred I have been on the look out for fresh opportunities, but you will readily understand that information of this sort is difficult to be obtained by one individual. Will you help me to examine such cases? When you hear of any unusual number of deaths among rats from plague, please let me know at once; and if we are unable to persuade the people to catch the fleas on their persons, I propose to use guinea-pigs to trap the fleas by placing these animals in the probably infected rooms, and then we shall be able to see whether rat fleas are straying about, for they will take to the guinea-pigs and can easily be captured on these animals.

If rats can communicate the disease to man, it is equally certain that man can carry the disease to rats. I have already explained how the disease can be communi-

cated to distant towns and villages from infected rats in one place to those in the other place by human agency. But there are other well recognised cases where infection has been carried from one village to a neighbouring village by man, where the possibility of the direct transference of infective rats from the one place to the other is absolutely excluded. The record of such cases is almost legion. I take 2 cases of 12 recorded in the excellent report on plague and inoculation operations in the Amritsar district in 1903, by Captain S. Browning Smith, I.M.S.

Kadgil.—(The name of the village.) Here the disease was brought from Tharu, by Buta, a weaver, in November 1902. He died after three days' illness, and three other deaths occurred in this house within five days; rats died in this house, and were allowed to remain, and the house was locked up; plague did not spread at the time, and no other case occurred for two months, when dead rats were noticed in some sweepers' houses that adjoined Buta's house; seven days after dead rats were seen, the disease appeared among the sweepers.

Phailoke.—The disease was brought from Chela, Lahore District, by Chet Singh, who returned to Phailoke on the 25th March 1903. Rats began to die on the 29th March 1903. Chet Singh fell ill on the 2nd April, and died on the 8th April. Three other cases occurred in the same house."

Captain Browning Smith remarks: "The above is a case where it seems that infection was brought in the clothes of the man; rats were infected from this, and the man himself was infected from the rats." The cases speak for themselves. The explanation I offer is that a man living in an infected village takes fright when he finds cases of plague occurring among others in his own house. The infection of this household was clearly brought about in the way I have described above, rats died, the remaining ones migrated, the hungry infected fleas they left behind attacked man; man became infected, some of these fleas having got among the clothes of the fugitive man, he has carried them to the village to which he has fled. The fleas may have in the meantime attacked him, and if so, he dies of the disease shortly after his arrival; but possibly the fleas may have failed to get through his clothes, the man then remains unaffected. When transferred to the new village in this manner, the fleas find themselves in fresh rat-infested premises, and are not long in scenting out their natural host, the rat. They infect the rats, the disease spreads among the rats rapidly they die; the rest take fright and migrate; man becomes infected.

But why press this flea theory, you will say, when we know perfectly well that the excreta from infected animals is capable of infecting fresh animals. This is a gratuitous assumption. Have you tried it? I have. Healthy rats can live in the same cage with infected rats without acquiring the disease, if only fleas are excluded. I told you of such experiments when I read a paper before you in March last year. Since then other persons have independently confirmed my observations, particularly Dr. Klein.⁹ I have been able to prove that although susceptible animals do take plague through the alimentary canal if fed on large quantities of grossly contaminated food, yet they can eat food, which has been contaminated by a relatively small quantity of plague without harm. Moreover, what is more important, they are not infected with the insufficiently large quantity of plague which is contained in the various excreta of plague-infected man or animals. I have fed rats on such excreta, and kept them in contact in a small cage with clothing which had been soiled by dying plague patients, and they have not suffered from the disease. But when even one or two germs are introduced by a needle under the skin, death almost always results. Thus, a guinea-pig has died of plague after receiving one quarter of a c.c. (about 4 drops) of a ten million-fold dilution of a 48-hours broth culture of plague. In this quantity I was able to show

there were not more than one or two germs. If only one or two germs are necessary to infect an animal by injection under the skin, while millions are necessary by any other channel which is more likely to be the common method of infection?

Simond¹⁰ long ago showed that phlyctenules (blisters occasionally found in cases of plague, and which reveal the point of inoculation of the bacillus) often occur in parts little liable to abrasion (such abrasions might permit the plague germs to enter the blood) but which are frequently attacked by fleas. If cuts and abrasions were the chief source of infection, phlyctenules would be commonly found on the soles of the feet of those who go about bare-footed, but this is not the case. Phlyctenules in this situation are extremely rare, while they are most common just in the situations which are most subject to be attacked by fleas. Again the boot-wearing people of Australia suffered as frequently from buboes in the groin as the bare-footed Natives of Bombay. 73 per cent in the one case, 67 in the other.¹¹ If the bacillus lived in the soil it would have been reasonable to expect a larger number of groin buboes in the bare-footed Natives than in the booted Australians. Moreover, the common sources of infection with plague are dark dirty over-crowded vermin-infested houses; also clothing and grain. It is just in these surroundings that fleas may be found. We know, too, that houses and clothing can be indirectly infective through the medium of a healthy uninfected individual. The healthy individual carries with him something, presumably infected fleas, to another individual who sickens with the disease.

The seasonal prevalence of plague can to my mind be most easily accounted for by the greater prevalence at some given time of some intermediary host of the plague bacillus after the same manner as the prevalence of malaria is associated with the prevalence at certain definite seasons of certain species of mosquitoes of the genus *Anopheles*. On several occasions fleas have been noted to be specially abundant prior to or during the course of an epidemic of plague. I will only mention two instances. Thus, for example, Dr. Tidswell's attention was directed early in the epidemic of plague in Sydney in 1900 to the unusual prevalence of fleas in the infected quarters. He writes: "At the time the rats were dying in large numbers upon the wharf, to which attention was called above, the fleas there were so numerous that the labourers tied string round the bottom of their trousers to protect themselves against the onslaughts of the vermin"¹². Again, in connection with the rat epidemic of plague at Cardiff in February 1901, I quote from the Local Government Board Report for 1902: "Fleas in considerable numbers were observed on the white flour sacks in the warehouse mentioned."¹³ I have on more than one occasion been told that before an outbreak of plague occurred fleas were noticed to be very prevalent; the only wonder is, as Tidswell¹⁴ has expressed it, that such a fact should have been noticed at all, for the social status and domestic habits of most people among whom plague occurs is not such as to invest a little incident of this sort with remarkable novelty. Finally, there are many facts to my mind which cannot be explained on any other hypothesis, I will only mention a few of them here.

Mr. Nigel Paton, who is in charge of a large oil store in Bombay, wrote to me after reading my paper published in the Medical and Physical Society's Transactions last year,¹⁵ that he had been at a loss to explain why every year during the plague epidemic he lost several hands employed by him in the office connected with the store, while, since the plague has broken out in Bombay he did not remember a single death from plague having occurred among the hands he employed in the store itself, although the hands employed in both departments lived in much the same manner, and in the same infected surroundings. Unfortunately he could not support the statement by statistics, but he said it was a well-known fact in the office, and had annually been

commented on. His explanation of the fact now is this, that men in the oil store itself were constantly handling oil, to such an extent indeed, that their bodies were covered with it; and he presumed that probably the smell of the oil, or some other cause connected with the oil, prevented the infected fleas biting the oil workers, and so they escaped the disease. Now Mr. Paton's experience is by no means unique. In 1797, it was observed by Mr. Baldwin, the British Consul in Egypt, that among the millions of inhabitants who died of plague in that country in the space of four years, not a single oilman or dealer in oil had suffered.¹⁶ Sir J. McGrigor remembered that all the men employed in applying oil to the camels' feet, during the Egyptian campaign, escaped the plague.¹⁷ Mr. Jackson states that the coolies employed in the oil stores of Tunis smear themselves with oil, and are rarely affected with plague when it rages in that city.¹⁸ It is also stated by Luigi of Pavia that during the 27 years he was attendant at the pest house in Smyrna, he found friction with oil more efficacious than any other medicine both as a prophylactic and as a means of cure.¹⁹ In the plague epidemic in India in 1815 and 1819 Mr. White, talking of the common practice in the many parts of India of friction to the body with oil says: "This (practice) has upon very good authority and extensive experience, been supposed a complete preventive, as well as a powerful agent in the cure of plague."²⁰ "Mr. McAdam says: "Another remark which the Natives make, and which I think is likely to be just, as they are not apt to take notice of anything that is not extremely obvious, is, that those engaged in the expression of oil are not liable to infection."²¹ Can the relative immunity of Calcutta and Madras compared with Bombay and the Punjab be due to the habit of daily anointing the body with oil in the former to presidencies? I was very much struck by this habit in Sambalpur, where recently I was Civil Surgeon; the people in this district follow partly the habits of the people of Calcutta and partly those of Madras.

I was informed that the Jubbulpore Municipality placed it on record during a very severe epidemic two years ago that tobaccoists who lived in their shops were peculiarly exempt from the disease.

It is notorious how frequently visits at night to plague-infected houses have been followed by fatal results, while the same houses could be entered with impunity by day. In this connection the following quotation from the report of Dr. Watson on the Mahamari (plague) of Kumaon is of interest:²² "The experience of Dr. Renny, Dr. Pearson, Dr. Francis and others has proved that a medical officer can without danger feel the pulse of a plague patient and give him medicine, and also that medical officers can without danger examine by dissection the body of a man who has died of plague." That is to say, he can do these things by day, with the sun shining and the air tolerably warm. I do not believe he could do any of them with immunity after night-fall. Take these facts in conjunction with the observations I have made that *Pulex cheopis* shuns the light, and the facts which I communicated to you in the paper which I read before you last year. I then told you that I had noticed that on certain days I was able to get many fleas from the rats sent to the Laboratory, while on other days none were obtained. As many as 53 rats on one day were examined and not a single flea was obtained, while on another day 13 rats yielded 22 fleas. In seeking for an explanation for this I noticed that when the rats were brought to the Laboratory in a dark iron cage, fleas were plentifully found on the rats, while when they were brought in an open wire cage no fleas were found on them. I also noticed that if the rats were kept in open cages in a light place all the fleas that were placed on them disappeared.

It would be possible thus to greatly enlarge upon this subject; but already I have occupied you far beyond the usual time devoted to a paper. I had sketched out in my plan of this paper a heading which was to

deal with the lessons to be learned from the facts placed before you. I cannot, however, do so to-day; perhaps some other opportunity may present itself. I will only say that it is obvious that any changes which will free Bombay or India of plague can only be introduced gradually, as the people become more educated and civilised, and learn that rats are the most important factor in the spread of the disease. If we cannot speedily place a distance between ourselves and rats, we can at least protect ourselves from the danger of their propinquity by acquiring immunity to plague by inoculation. This is to my mind the only measure that offers any hope in combating the disease in the near future.

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- (15) Liston, Transactions of Bombay Medical & Physical Society, February 1903.
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- (18) On the Commerce of the Mediterranean, p. 46.
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- (21) Transactions of Bombay Medical & Physical Society, Vol. I.
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SOME CLINICAL FEATURES OF QUARTAN MALARIA.*

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THE most striking feature of the series of cases of quartan malaria on which my observations have been made has been the absence, in the majority, of the characteristic quartan pyrexia. The extraordinary periodicity of the pyrexia, which gave a name to the fever in ages long gone by, and which enabled the physicians of those days to differentiate it from the host of other fevers, was absent in no less than 60.6% of my cases. But for the examination of the blood, the essential element in many of the cases would have been overlooked, and the treatment futile.

In this outline of the clinical features of the disease, I will not attempt to describe all the well-known symptoms and stages of a simple case of the fever. Suffice it to say, the headache, malaise, shivering, etc., were present to a greater or less degree in all cases. These simple cases were in the minority, and in depicting the clinical aspects of the majority, I cannot do better than group the cases according to the symptom which was most prominent in the patient's mind, the one which, in fact, brought him to the hospital.

(1) *Fever*.—Although the fever was not characteristic in many of the cases, it was by no means absent in the

majority; in some there were daily rises of temperature in others an occasional rise at long intervals. Of a total of 83 cases, 1 absconded on the day of admission, 16 received quinine within three days of admission, and 66 did not receive quinine for at least three days after admission. Taking cases with pyrexia attacks separated by two days of apyrexia, and those with two days of pyrexia separated by one day of apyrexia, as recognisable single and double infections—the 66 were divisible into 26 recognisable (23 single and 3 double infections), and 40 unrecognisable as quartan malaria.

The reasons for these 40 cases being unrecognisable were the following:—In 16 there was an irregular pyrexia, for the most part quotidian; in 9 the temperature rose once in an average of 8.8 days (i.e., once in 12, 10, 8, 13, 6, 5, 7 and 9 days respectively; in 2 of which the rise occurred on the 9th day of admission); in 2, the temperature rose twice in 13 and 18 days respectively; in 1 it rose thrice in 18 days; and in 12, it was normal for periods averaging 6.4 days (7, 2, 12, 9, 8, 3, 4, 11, 4, 6 days, after which quinine was administered although the temperature remained normal).

The following table shows an Analysis of the Temperature Charts of 66 cases of quartan malaria:

	Nc. of Cases.	Percentage.
Recognisable (single or double) ...	26	39.40
Unrecognisable Pyrexia, mainly quotidian	16	24
Do. do. at long intervals	12	18.18
Do. do. absent ...	12	18.18
	16	10.00

It is thus seen that in 36.36% of the cases pyrexia was noticeably absent, and in 18.18% the temperature was normal. Of the 12 cases with normal temperatures, 4 had triple infections.

Under the microscope the infection was recognised as triple in 30, double in 8, and single in 44 cases; while in one with the characteristic temperature chart of a single infection, prolonged examination of the blood from the finger and the spleen revealed numerous unpigmented amoeboid parasites and crescents, but not a single pigmented parasite distinguishable as quartan.

Before passing from the subject of temperature the great tendency towards the disappearance of pyrexia by simple rest in bed should be noted. In 14 cases the temperature became, and thereafter remained, normal in an average of 3.4 days.

In a few cases, an attack was missed, but was succeeded by one due to the same parasitic group.

Cases 767, 617 and 222, 965, 436 illustrate some of these points.

(2) *Œdema*.—After fever, the patient usually complains of swelling. This varies in amount; in some there is only slight œdema of the feet; in others it is a more prominent feature, but is still moderate in amount, involving at times the legs and hands, at other times eyelids; while in a third group, the legs, arms, abdomen, chest and face are greatly swollen, the pleural cavities half filled with fluid, the lungs water-logged and full of moist râles, and the patient will sit up gasping for breath. In these cases of severe hydræmia the condition directly threatens the patient's life.

In these cases, the patient may complain of fever, or there may be pyrexia of which the patient is unconscious, or there may be a normal temperature for considerable periods at a time.

There is usually a loud hæmic murmur at the third left costal cartilage, and there may be murmurs at the tricuspid and mitral valves. Examination of the urine may reveal nothing abnormal, or the urine may throw

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